U.S. Mines. Bur. of

Technical Paper 97

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
VAN. H. MANNING, Acting Director.

SAVING FUEL IN HEATING A HOUSE

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ENGINEERING
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BY

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AND
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First edition. August, 1915.
Reprint. October, 1915.
Revised reprint. December, 1916.

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SAVING FUEL IN HEATING A HOUSE.

By L. P. Breckenridge and S. B. Flagg.

INTRODUCTION.

The total output of coal in the world during the calendar year 1913, according to a Government report,[a] was 1,443,393,052 short tons, and of this enormous amount 39.5 per cent, or 570,048,125 tons, was mined in the United States. Probably 10 to 15 per cent of the coal produced in this country went to purchasers who used it largely for heating dwellings. The Federal Government uses a large quantity of coal for heating the many small buildings occupied by its various departments and bureaus, and is therefore directly interested not only in selecting proper fuels but in obtaining the best possible results from their consumption. Because of this interest on its own account and the widespread interest of householders the Government some years ago conducted tests to determine the relative value, for use in residence-heating boilers, of several typical fuels.[b]

The value a householder gets from the fuel he burns depends largely on the character of the heating apparatus, the conditions under which it is installed, and the manner in which the fire is handled. The authors, from experience in firing residence-heating apparatus and from observing the methods employed by many who attend to such apparatus, keenly appreciate the importance of proper firing methods, and have written this paper in the belief that some general remarks on the selection, care, and operation of residence-heating apparatus may prove of value to many who are interested in burning fuel in the most economical manner.

ACKNOWLEDGMENTS.

The authors are indebted to O. P. Hood, chief mechanical engineer of the Bureau of Mines for helpful suggestions, to Prof. E. H. Lockwood, of the Sheffield Scientific School, Yale University, for the record of fuel consumption in his own home, and to the H. B. Smith Co., of Westfield, Mass., and the American Radiator Co., of Chicago, Ill., for information on heating equipment and its operation.

[a] Parker, E. W., The production of coal in 1913: Mineral Resources U. S. for 1913, U. S. Geol. Survey, 1914, pt. 2, p. 783.

[b] For results of these tests see Randall, D. T., Tests of coal and briquets as fuel for house-heating boilers: Bull. 27, Bureau of Mines, 44 pp.

FUELS USED FOR HEATING RESIDENCES.

Most people when fuel for residence heating is mentioned think of the particular kind that they are accustomed to use, but, of course, all people do not use the same fuel. Locality, climate, cost, and other considerations govern the choice, and the fuel used may be wood, anthracite, bituminous or subbituminous coal, lignite, peat, coke, oil, or gas. Even electricity may be used.

WOOD.

Wood is little used for heating residences except in those regions where it is plentiful and other fuels are relatively expensive. Some people in places where coal is the usual fuel burn wood in open grates because of the cheerful appearance of the fire, but the quantity of wood available for fuel is becoming less and less. Because of the relatively high percentage of water in wood—usually between 15 and 40 per cent—the amount of heat obtainable by burning a pound of wood is relatively small.

ANTHRACITE.

Many people select anthracite for residence heating because it is clean, but additional reasons are its fairly high heat value, the relative ease with which a reasonable proportion of this heat value can be realized by heating apparatus, the easy control of the fire, and particularly the long period for which the fire may be left without attention. But anthracite is becoming more expensive and therefore its use is being restricted.

BITUMINOUS COALS.

The bituminous coals vary so much in composition and in physical characteristics that they can hardly be considered as one class. In general it may be said that the bituminous coals mined in the eastern part of the United States are of higher rank than those produced farther west, having usually a greater heat value, less inert matter (or ash), less moisture, and a smaller proportion of gaseous constituents, or, as these are ordinarily termed, volatile matter. Bituminous coals also differ widely in coking properties; those mined in the Eastern States tend to coke or cake together when heated in the furnace, and with many of them the tendency is very decided, whereas coals of the same general class mined in some of the States farther west have little or no tendency to coke, and still other western coals have much the same coking properties as do the eastern coals. The bituminous coals constitute a large part of the fuel used throughout the country for heating purposes, for the reason that they are the most readily available and the cheapest fuel.

The different bituminous coals vary greatly in heat value, some of them ranging as high as 14,700 and others as low as 8,500 or 9,000 British thermal units per pound, a British thermal unit being the quantity of heat required to raise the temperature of 1 pound of water 1° F. Ordinarily, the heat value of a fuel is determined by burning a small quantity of the fuel inside a water-jacketed steel bomb containing oxygen gas under pressure. The heat generated by the burning of the fuel raises the temperature of the water surrounding the bomb and by knowing the quantity of fuel burned, the amount of water in which the bomb is immersed, and the rise in temperature of this water, it is possible to compute the number of heat units that 1 pound of the fuel will generate.

SUBBITUMINOUS COAL, LIGNITE, PEAT.

Subbituminous coals, lignites, and peat are ordinarily used within comparatively short distances from where they are produced. Both the subbituminous coals and the lignites slack or break into small pieces, on exposure to the air. This unfavorable feature and the further fact that neither of these fuels can be stored without danger from spontaneous combustion, as well as the usually low heat values, limit the area within which they can profitably be transported and used.

The peat bogs in the United States have not been largely utilized as sources of fuel, because of the abundance of fuels of higher grade. Most peat when dug from the bog contains 90 per cent by weight of water, and the commercial processes of making peat fuel involve maceration of the wet peat, moulding into bricks, and drying by exposure to the air. Artificial drying in ovens or kilns is possible but is expensive. Because of the cost of preparing peat fuel and the abundance of other fuels in this country, it is probable that the use of peat for heating residences will not increase greatly in the near future.

COKE.

The coke used in residence heating is obtained from three sources: (1) from retorts of coal-gas plants, as the residue after the gas has been driven from the coal; (2) from by-product coke plants, which are built to produce coke and to obtain gas and other by-products; and (3) from beehive ovens, which are built to produce coke only. In some places retort coke from coal-gas plants has long been used for residence heating, but until recently the quantity so used has been small. Beehive coke is not extensively used as a household fuel, but in some places the demand for it is considerable and its use is increasing. By-product coke ovens are increasing rapidly and household use of by-product coke is growing apace. Lack of information as to the proper methods of burning explains largely why coke has not been more generally used. Recently manufacturers

and distributors of coke have done much to supply such information, and have emphasized the advantages of coke as a household fuel, the principal one being cleanliness.

FUEL OIL.

The use of oil fuel for house heating, except in the small kerosene stoves employed by some people to supplement other means of heating, is confined almost entirely to those districts where oil is plentiful and the price of other fuel is relatively high. Oil-burning stoves are used with wickless ("blue flame") burners in which the fuel is vaporized after the stove has been given a preliminary warming. The distillate used in such stoves somewhat resembles ordinary kerosene but is slightly heavier. These stoves would hardly prove satisfactory for heating dwellings in localities where winters are severe, but they serve well in places where the climate is relatively mild and heat is required only at times and for a few hours at a time.

GAS.

Gas is the ideal fuel. Within the last few years the use of gas stoves for cooking has not only become common but in many cities is displacing stoves using other fuels. Lower prices for gas are largely responsible for this increase but convenience and cleanliness are factors of possibly equal importance. The gradually increasing cost of anthracite is causing not a few people to consider gas as a fuel for residence heating and it is probable that the use of gas heating appliances will increase. In some localities natural gas is so cheap that its use is common and continues until the cost of transportation from distant fields makes the price of this fuel prohibitive.

HEATING WITH ELECTRICITY.

Electricity is little used as a principal means of heating dwellings, except in those localities where hydroelectric plants have been erected in connection with irrigation projects and the demand for current for power and lighting is still too small to make an economical load for the generating station, thus making advantageous the sale of current at a low rate for heating purposes. If, as sometimes happens, the cost of coal or other fuel for domestic heating is high in such localities, it may be possible to heat by electricity without great increase of expense and with a minimum of work and inconvenience. Under conditions other than those just mentioned, the cost of heating by electricity, except for short periods when a supplementary means is required, will probably for some time be high enough to prevent a large use of electric heaters. The reason for this is that in present methods of generating electric power in large stations the heat derivable from a certain amount of electric energy is only a small part—

between 7 and 20 per cent, according to conditions—of the heat represented by the solid or liquid fuel required to drive the generators. In other words, the conversion of fuel energy into electrical energy involves such large losses that most people for some time to come will not use electricity for warming dwellings.

ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT FUELS.

Some of the advantages and disadvantages of different fuels for residence heating have been mentioned. These and some others that have not been stated are summarized in the following table:

Advantages and disadvantages of various fuels and of electricity.

Fuel.	Advantages.	Disadvantages.
Wood	(*a*) Cleanliness, (*b*) cheerful fire, (*c*) quick increase of heat, (*d*) cheap in some localities.	(*a*) Low fuel value, (*b*) large storage space necessary, (*c*) labor in preparation, (*d*) scarcity, (*e*) does not hold fire long, (*f*) unsteady heat.
Anthracite	(*a*) Cleanliness, (*b*) easy control of fire, (*c*) easier to realize heat in coal than is the case with other coals, (*d*) steady heat.	(*a*) High price, (*b*) difficulty of obtaining, (*c*) slower response to change of drafts.
Bituminous coal	(*a*) Low price, (*b*) availability, (*c*) high heat value (in the best grades), (*d*) low percentage of inert matter (in the best grades).	(*a*) Dirty, (*b*) smoke produced, (*c*) more attention to fire and furnace necessary than with anthracite.
Subbituminous coal and lignite.	(*a*) Relatively low price, (*b*) availability (in some regions), (*c*) responds quickly to opening of drafts.	(*a*) Slakes and deteriorates on exposure to air, (*b*) takes fire spontaneously in piles, (*c*) heat value generally low, (*d*) heat in fuel difficult to realize, (*e*) fires do not keep well, (*f*) gases generated over fire pot sometimes burn in smoke pipe, causing excessive heating.
Peat	(*a*) In general, the same as for wood.	(*a*) Low heat value, (*b*) bulkiness.
Coke	(*a*) Cleanliness, (*b*) responds quickly to opening of drafts, (*c*) fairly high heat value.	(*a*) Bulkiness, (*b*) liability of fire going out if not properly handled, (*c*) fire requires rather frequent attention unless fire pot is deep.
Oil	(*a*) High heat value, (*b*) immediate increase of heat, (*c*) cleanliness, (*d*) small storage space necessary.	(*a*) High price, (*b*) difficulty of safe storage.
Gas	(*a*) Ease of control, (*b*) cleanliness, (*c*) convenience, (*d*) immediate increase of heat.	(*a*) High price in many places.
Electricity	(*a*) Every advantage	(*a*) High price.

METHODS OF HEATING RESIDENCES.

FIREPLACES.

The first fuel and for centuries the chief one used in residence heating was wood. Heating and cooking operations were often combined and the old open fireplace with its immense chimney served for both purposes, although in spite of some obvious advantages it was not adapted to produce economically and efficiently the heat needed for either. The need of improved devices was probably more keenly felt in cooking than in heating, and the use of stoves for cooking became quite common while the open fireplace, in a modified form, was still employed to heat the house.

In any open fireplace, however, close control of the combustion of the fuel is difficult; and large volumes of air not necessary for combustion are, after being heated, carried up the chimney and must be replaced by cold air from outside, which must be heated in turn. One of the most important considerations in economically utilizing any fuel is proper regulation of the volume of air supplied the fire. A familiar illustration of this fact is afforded by the mantle burner for gas lighting. In the best makes of these burners there is provision for controlling the supply of both gas and air, the most intense heat, and consequently the best light, being obtained when the supply of both air and gas is properly adjusted.

STOVES.

Stoves with dampers in the smoke pipe and with draft slides in the fire and ash-pan doors afforded some regulation of the air supply and in addition served to confine and conserve the heat generated so that it could be more effectively utilized. Stoves were developed for burning not only wood but also coal, oil, and gas, although the invention and perfection of more desirable types of heating apparatus served to check the improvement of stoves in this country. In the United States, owing to the comparative abundance and cheapness of fuel, the demand in residence heating has been not only for a higher temperature standard but also for greater convenience of operation and perfection of control. In foreign countries much less use is made of what in this country are considered the best methods and equipment for residence heating, but, on the other hand, stoves have been more highly developed there. Some foreign stoves burning what is considered in this country much poorer fuel offer almost the same perfection of control and ease of operation as the anthracite "base burners" or "self-feeders," formerly so popular.

HOT AIR, STEAM, HOT WATER.

The next step toward greater convenience in heating residences was the substitution of one fire in the cellar or basement for separate fires in each room. To convey the heat from the point of generation to the rooms, three general systems have been developed—air, steam, and water heating.

HOT-AIR HEATING.

The simplest apparatus for heating a house, as well as the cheapest in first cost, is the hot-air heating system. The air to be circulated, taken through a duct from the outside of the building or from the lower part of the house, passes through the air passages of the furnace, which are heated by the fire or the hot gases from it, and then

is distributed through pipes and registers to the rooms to be heated. The air in the circulating pipes is expanded by heating and becomes lighter than the air that enters the furnace passages or the air in the rooms, so that when the registers are open and the furnace is in operation a stream of heated air enters each room.

As the warm expanded air leaving a register can hold much more moisture than the cooler denser air that entered the heating passages of the furnace, it has a drying effect and may cause cracking of furniture and woodwork in the rooms heated. To reduce the dryness of the air, moisture may be added to it by evaporating water in the hot-air passages of the furnace or in other ways.

Difficulty may also be experienced in heating an exposed dwelling by hot air on a cold, windy day. As the rooms are warmed by the movement of heated air, that is, by the convection of heat, there is more tendency for the windward side of a house to be cold and the leeward side to be warm than when the rooms are warmed, at least partly, by direct radiation from steam or hot-water radiators. Limitation of trouble from this cause will largely depend on how well the house is built.

STEAM AND HOT-WATER HEATING.

When steam or hot-water heating is to be used radiators are placed in the different rooms, usually near the windows, and these are connected with the steam or hot-water boiler in the basement by means of suitable piping. Steam radiators may be smaller than hot-water radiators and yet give off more heat, because the temperature of the steam radiators usually will exceed 212° F., the exact amount depending on the steam pressure in the radiator, whereas hot-water radiators will usually have a temperature between 90° and 180° F.

For warming a given space, the first cost of a hot-air system of heating will be less than that of either hot water or steam, largely because of the cost of the radiators, and the initial outlay for steam heating will be less than for hot water. The relative costs of operation, however, are apt to be in the reverse order, although the differences in operating costs will be problematic.

One of the desirable features of a hot-water heating system is the possible range in temperature of the water, enabling the heat to be varied according to needs. Such variation is not possible if the house is heated by the usual low-pressure steam system, neither can the output of a steam radiator be reduced by partly closing the valve, as is possible with a hot-water system, unless the piping and fixtures are rather elaborate. On the other hand, a steam heating system can respond to sudden demands for heat much more quickly and the radiators required are somewhat smaller.

FACTORS AFFECTING DESIGN OF HEATING APPARATUS.

In the development of new types of heating devices or in the improvement of existing types, the chief factors influencing design are two. The first is maintenance of more satisfactory temperature conditions with the same or less inconvenience of operation, manufacturers of heating appliances endeavoring to produce heaters that will go for longer periods without attention, or can be given necessary attention with a minimum number of trips to the basement. The second factor is the desire to utilize more efficiently the available heat in the fuel. Owing to the abundance and relative cheapness of fuel in this country, the incentive to efficient utilization has not been strong, but as the cost of fuel and of other necessaries increases, economy and efficiency will receive more and more attention. Inasmuch as the design of the apparatus is only one of the elements that determine the annual fuel bill, the factors that govern consumption of fuel and convenience of operation are considered here.

FACTORS GOVERNING CONSUMPTION OF FUEL AND CONVENIENCE OF OPERATION.

CLIMATE.

Some factors that greatly affect the total consumption of fuel are not at all related to fuel economy; one of these is climate. It is obvious that in northern Maine much more coal or wood will be needed to heat a house of a certain size to a certain temperature on a January day than will be needed in southern Georgia. In this instance the difference of outdoor temperature is great, but a smaller difference will have an effect. Variable weather always makes difficult the economical use of fuel; high winds likewise are unfavorable because of the volume of cold air that enters a house. Convenience of operation will also be affected by climatic conditions, being favored by even but not too low temperatures and by lack of high winds.

SIZE AND TYPE OF DWELLING.

Other things being equal, fuel consumption will, of course, vary with the size of the house and the number of rooms heated. Nevertheless many people do not give this point due consideration when comparing coal bills for a year, and do not take into account differing requirements of temperature and duration of heating.

In addition, satisfactory heating and the quantity of fuel required will depend largely on the construction of the house. As a rule, a stone or brick house will be more easily and economically heated than a frame house, although substantial and thorough construction are of greater importance than the building material. Ill-fitting doors and window frames or sashes, especially in a house exposed to high winds,

may make economical heating impossible with any boiler or furnace. Double or storm windows and weather strips will materially lessen the quantity of fuel consumed and the amount of attention required by the heating apparatus.

Even the distribution of radiators affects the cost of heating, for where they are not well distributed it is necessary to maintain them at too high a temperature in order to warm the cool corners of a room.

LOCATION OF DWELLING.

The location of a house with reference to exposure to winds is a large factor in determining the difficulty of warming it. Between a 10-room house standing alone on a bare hill and a house of like size and excellence of construction, but the middle one of a closely-built row standing in a hollow, there will be a marked difference in heating cost.

HEATING AND VENTILATING SYSTEM USED.

Convenience of operation of any house-heating apparatus is largely dependent on the system of heating and ventilation employed. The cost of heating will also depend, but to a less degree, on the type of equipment. Fuel economy and convenience are against a separate fire in each room unless the house is small or only a small part of it is to be warmed, except in those localities where natural gas is available at low rates or the duration of cold weather is brief.

In most houses there is no positive system of ventilation; in fact, except in sleeping rooms during the night, little or no provision is made for the admission of fresh air. Nearly all houses warmed by hot-air furnaces have ducts to take from outdoors the air to be heated and delivered to the different rooms. In dwellings heated by an indirect system, whether steam or hot water, the heating coils are in ducts through which the outside air enters. In comparatively few homes is any special provision made for removing the foul air, leakage from windows and doors being the usual reliance, particularly in a house heated by a hot-air furnace. If an indirect steam or hot-water system is installed, means of removing foul air are more frequently provided, either by vent stacks leading into the attic or through the roof, with register openings in different rooms, or by open grates, the flues for which can be equipped with dampers to regulate the removal of foul air. The system sometimes fails to work satisfactorily if provision is not made for the escape of foul air from a room, as the fresh warm air will not continue to flow in unless an equal amount escapes.

As already stated, the first cost of heating by the hot-air furnace is less than that of either the steam or the hot-water system, but to maintain equal temperature conditions may require the burning of more fuel, whether the furnace heats air taken from outdoors or

reheats air already in the house. Evidently, reheating air will require less fuel, and consequently less attention to the furnace, than heating fresh air, but the ventilation will not be good.

Some furnaces have the cold-air duct so arranged that some of the air may be taken from outdoors and the rest from inside the house, the proportion of fresh air being regulated by dampers in the two branches of the cold-air duct. In homes heated by steam or hot water, the method of heating, whether direct or indirect, and the provision, if any, for removing foul air will affect the consumption of fuel, which will vary with the percentage of the total radiation that is indirect and with the amount of warm air removed through vent stacks or grates. Owners of houses heated by different methods sometimes compare results and draw conclusions as to relative advantages of each system. If the houses are similarly situated and constructed and like conditions are maintained, these comparisons are of value, but such similarity is rare. The important bearing of ventilation on the fuel consumption may be illustrated by computations of the heat required for a two-story brick and frame house. These computations show that if the air in the rooms is to be changed once an hour the amount of "radiation," or the quantity of heat to be delivered into the rooms, must be 25 to 30 per cent more and if the air is to be changed twice an hour the "radiation" must be 50 to 55 per cent more than without ventilation. When many persons are in a room it costs more, as a rule, to heat the air needed for ventilation than to supply the heat radiated from the building.

LIFE OF HEATING APPARATUS.

Another point to be considered in a discussion of the relative merits of systems of heating, although not one affecting so directly the fuel consumption or the convenience of operation, is the life of the apparatus or equipment. Ordinarily, but not always, a steam or hot-water boiler may be expected to be in serviceable condition after two hot-air furnaces have served their day and been replaced. To install a steam-heating system in a house of average size will cost, roughly, twice as much as to put in a hot-air system and somewhat less than to install a hot-water system, but the higher first cost of a steam or a hot-water system will in a measure be offset by low outlay for repairs or renewals.

CONVENIENCE OF OPERATION.

As regards convenient and satisfactory operation, although much depends on factors other than the system of heating, yet each system has certain inherent advantages and disadvantages, some of which have been pointed out. With either a steam or a hot-water system of heating, radiators may be placed at any desired point in a room, although there is a prevailing belief that the radiators must be put

in front of the windows to warm the cold air that descends from the glass cooling surface or enters about the sash or window frame. With a hot-air furnace there is a possibility, especially after the furnace has been in use for some time, of smoke and gases from the fire leaking into the air passages and being carried to the rooms, whereas with a steam or hot-water system there is ordinarily no chance for such leakage. If the house is not tight, the distribution of heat from a hot-air furnace to the several rooms is easily disturbed by the wind and is less positive than with either a steam or a hot-water system and at times there may be trouble in heating the windward side of the house. Also, a furnace-heating system maintains a less even temperature because less heat is stored in it. In this respect, hot-water heating has a distinct advantage over both steam and hot air because the large quantity of water in the boiler, pipes, and radiators can maintain the temperature throughout the house for a considerable time after the fire dies down. In addition, the maintenance of an even temperature in mild weather is easier with the hot-water system because the temperature of the water in the radiators, hence the amount of heat given off, can be controlled within wide limits.

SIZE OF BOILER AND FURNACE.

SIZE OF FIRE POT.

The type and size of the boiler or furnace selected is also an important but not generally recognized factor in determining fuel consumption and convenience of operation. Until the last five years both makers and buyers of house-heating boilers and furnaces gave little thought to the fuel to be burned. This neglect was a natural consequence of anthracite coal being generally used both in the east, where much of the heating apparatus was made, and in many places farther west, and tests to determine the boiler or furnace capacity required to heat dwellings of various sizes were conducted with this fuel. In fact, the ratings published to-day for much heating equipment are based on the use of one of the larger sizes of anthracite. The sizes ordinarily used for domestic service weigh approximately 55 pounds to the cubic foot, whereas bituminous coals weigh from 47 to 52 pounds and coke from 30 to 40 pounds to the cubic foot.

To warm the air in a house and to supply the heat lost from the windows and walls a certain quantity of fuel must be burned in the heater, this quantity depending on the heat value of the fuel, the efficiency with which it is utilized, and on other factors. If to supply the necessary heat requires the consumption of 20 pounds of fuel per hour and the boiler or furnace is to keep this up for eight hours without attention, it is evident that the fire pot must be large enough

to hold 160 pounds of fuel, and in addition the quantity necessary to rekindle a fresh charge, this quantity being ordinarily assumed to be 20 per cent of the quantity of fuel in the fire pot after the firing, or in this case 40 pounds. Hence the fire pot must hold 200 pounds of fuel and still leave space for combustion.

If anthracite coal, bituminous coal, and coke are available and each has such heating value that 20 pounds of it will be required per hour to supply heat, the fire pot space occupied by an 8-hour charge of each fuel may be figured by dividing 200 by the weight per cubic foot of each fuel, the space thus calculated being approximately 3.6 cubic feet for anthracite, 4.0 cubic feet for bituminous coal, and 5.7 cubic feet for coke. Therefore if the fire pot were designed for anthracite, it would hold coke enough for a firing period of approximately five hours instead of eight.

DEPTH OF FIRE POT.

Not only is the capacity of the fire pot important, but its depth should receive consideration. If the full rated load is to be carried without attention to the fire for a minimum period of eight hours, the depth of the fuel bed should be at least 12 inches. A heater that is to burn coke should be designed for a greater depth—probably 24 inches—on account of the bulkiness of the fuel and the different combustion conditions required for burning it satisfactorily. In fact, one of the largest manufacturers of boilers for heating houses by steam or hot water now designs such equipment for a fuel bed 18 inches deep when anthracite is to be used. As regards necessary size of fire pot, another detail that affects both economy and convenience of operation is the combustion space above the fuel bed.

Any unburned combustible gases that leave the fire pot are rapidly cooled in passing over the heat-absorbing surfaces between the fire pot and the smoke pipe, and their temperature is quickly brought below that necessary for ignition. If either anthracite coal or coke is to be burned, a relatively small combustion space above the fuel bed will be required because combustion takes place in or close to the fuel bed. If bituminous coal is to be used, however, more space should be provided for burning the combustible gases rising from the fuel bed, or a considerable part of these gases will escape unburned, the flue surfaces will become coated with soot, and the heat losses will be large.

PASSAGES FROM FIRE POT TO SMOKE PIPE.

Another important detail, if bituminous coal is to be used, is the cross section for the gas passages between the fire pot and the smoke pipe. If the passages are not large enough the draft may be cut down

by the accumulation of soot in the flues possibly to such an extent that the fire will go out. Also, if bituminous coal is to be used the flues should be of such size and so arranged as to invite frequent and easy cleaning.

GENERAL CONSIDERATIONS.

The effect of the size of the boiler or furnace on convenience of operation can probably be more readily seen than the effect on fuel consumption. Obviously if the heater be smaller than the proper size, firing at shorter intervals will be necessary, drafts will have to be kept open, and the temperature of the escaping gases will be higher than if a heater of proper size is installed—between 375° and 475° F. in ordinary winter weather. The inconvenience resulting from too large a boiler or furnace is less than from one undersize, but careful handling will be necessary to control the fire satisfactorily in mild weather.

As regards the increased fuel consumption resulting from a heater being too large or too small, each hot-air furnace, steam boiler, or hot-water boiler has certain limits of capacity or rates of working within which it will do its work most economically. Below or above these limits a smaller proportion of the available heat in the fuel will be utilized in heating; in other words, the efficiency of the heater will be lower. Each heater has a particular capacity at which its efficiency is highest, but if the heater be properly designed, within a certain range of capacity the efficiency will be practically equal to the maximum. Obviously the equipment selected should be one that during most of the heating season will be operated within these limits, but will take care of maximum demands for a short time. In some European countries where fuel is relatively much more expensive than with us, some of the larger residences have two or more heaters and as many of these are used as the weather makes necessary, so that each is kept working within the most economical limits.

KIND OF FUEL USED.

Another factor determining fuel consumption and convenience of operation of heating apparatus is the kind of fuel to be used. As a rule, fuels are like other commodities in that the most desirable are the most expensive.

As previously pointed out, the ideal method of heating so far as convenience of operation is concerned is by the use of electricity, but the cost is ordinarily prohibitive. The situation in regard to the use of gas in house-heating boilers or furnaces is much the same except in those localities where natural gas is available at low rates.

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ANTHRACITE.

Because of the desirable features of anthracite as a house-heating fuel, the consequent demand for it, and the increasing cost of production, the prices of the larger sizes have gradually increased. Many people who formerly burned nothing else in house-heating apparatus have come to feel that the convenience resulting from its use costs too much, and have changed to bituminous coal. Just what premium a householder will pay for this convenience can not be told, for it will depend on the locality and other factors. In some instances the higher cost of a more desirable fuel may be partly offset by a smaller cost of attendance, but usually such a saving will be negligible.

It may be possible, however, to burn some of the smaller sizes of anthracite with the furnace or egg size and thus effect a saving. The price per ton of these smaller sizes is less in proportion to their calorific value because they are in less demand and they can be used to advantage in banking the fire over night or in carrying a slow fire in moderate weather. Pea coal is probably the best size for such use, but unfortunately it and the smaller sizes are obtained with difficulty in many of the markets where the larger, or domestic, sizes are sold. The quality of anthracite sold by different dealers may differ decidedly, not so much from differences in the character of the coal in different mines as from differences in the carefulness of preparation at different mines, and of breakage in handling. Such differences will manifestly affect both the consumption of fuel and the attention needed by the fire.

BITUMINOUS COAL.

Among the various kinds and grades of bituminous coal the differences in fuel value and in their physical characteristics are much greater than among anthracites, and for that reason should receive especial attention. In every locality a number of coals will be available and the most satisfactory one in any particular case will usually have to be determined by trial, unless the characteristics of each and the effects of these are known.

Uniformity of size is a desirable characteristic, as it permits easier control of the fire. This is particularly true of anthracite, a mixture of sizes often accounting for poor results from a certain lot of coal. Sized or screened bituminous coal may be bought for its greater convenience, even though its cost may exceed that of lump coal or run-of-mine. In some localities slack coal has been burned successfully by some people, although it is believed that this would not ordinarily be possible because of the strong draft required.

CARE OF FURNACE.

Unquestionably with any fuel the prime factor determining fuel consumption and freedom from operating troubles, although it may generally not be so recognized, is method of operation. Inasmuch as the proper methods of firing different fuels are discussed under another head, the authors will consider here only some general aspects of the subject.

The person most likely to be interested in proper methods of operation is the one who pays the fuel bills, and as a rule therefore it is to be expected that better results will be obtained if the firing is done by the householder than if some one is hired to tend the fires. However, something more than an interest in keeping down the coal bills is necessary; some knowledge of the characteristics of the fuel and of the functions of the different parts of the heater is required to save fuel and trouble.

REGULATION OF DRAFT.

Many furnaces or boilers are operated in a haphazard way—drafts are opened or coal is put on when the house becomes cool, and then the fire is allowed to burn rapidly until either the rooms are too warm or the fuel bed is burned down too far to kindle properly a new charge of coal.

Such firing is always wasteful. The heater should receive regular attention, and if the demands for heat are intelligently anticipated, as they ordinarily can be, the house can be warmed with minimum trouble and fuel. When the rooms become too warm the fire should be checked by stopping the admission of air under the grate and decreasing the draft by opening the "check damper." If, as often is done, the ash-pit damper or the ash-pit door be allowed to remain open and the draft reduced by opening the fire door, the combustion of the fuel continues, although at a slower rate, but the cold air entering the fire door chills the heater so that little heat is realized from the coal.

Sometimes the draft is so strong that the difficulty of controlling the fire is increased, especially when the demand for heat is small or the fire is to be banked. To facilitate control under such conditions it is usually advisable to have, besides the check damper, a plain damper in the smoke pipe. This damper should fit the smoke pipe loosely and must never be entirely closed; during most of the heating season it can be kept partly closed, but during severe weather, when more heat is required, it can be opened wide. Sometimes the draft may be insufficient to burn the necessary quantity of the particular fuel used. If such a condition is always noticed in severe weather, the heater may be too small, the smoke pipe may be choked or be poorly

fitted to the heater or to the chimney, or the chimney may be too small or be obstructed by soot or débris. As to the size of smoke pipe and chimney, one authority[a] says that the cross-sectional area of the smoke pipe should be one-eighth of the grate area, that the diameter of a round chimney should be 2 inches more than that of the smoke pipe, and that if the chimney be square the inside length of a side should be $1\frac{1}{2}$ inches more than the diameter of the smoke pipe.

If the draft trouble proves to be due to leaky connections or to obstructions it can readily be corrected. If the heater or the chimney be too small the difficulties may be lessened either by firing more frequently and keeping the fuel bed thinner, or by using larger coal, of fairly uniform size, in order that the air may more easily flow through the fuel bed. Conversely, if the draft is very strong a smaller size of coal may possibly be used to good advantage.

To burn a pound of coal requires much more than a pound of air, and the volume of a pound of air at atmospheric pressure is far greater than that of a pound of coal. To burn more coal requires more air, and this air must be forced into the ash pit and up through the fuel bed by the difference between the pressure of the hot air and gases over the fire pot and that of the air entering the ash pit—in other words, by the "draft." This difference in pressure may be affected by various causes, some of which have been mentioned, but depends largely on the height of the chimney, which in turn is determined in a measure by the general design of the house. Under no circumstances should the top of the chimney be lower than the highest part of the roof, or a current of air may be forced down the chimney and the basement be filled with smoke when the wind blows in certain directions. Similar trouble may be experienced if the chimney is not as high as an adjoining building.

REMOVAL OF ASHES.

Usually the most disagreeable feature of tending house-heating apparatus is the removal of the ashes, and the possibility of facilitating the handling of ashes should receive attention when a heater is installed. If the bottom of the ash pit is on a level with the floor or only a short distance below the grates, as is ordinarily the case, ashes can not be allowed to accumulate under the grates for more than two days, or possibly more than one day, except in moderate weather, and must either be carried from the basement then or stored there and removed later. In any case the ashes must be shoveled at least once with the consequent scattering of dust. Some heaters are now set with a recess under the base, this recess holding

[a] Greene, A. M., jr., Elements of Heating and Ventilation.

a can into which the ashes drop directly. The recess must be so constructed as to permit easy removal of the can and to prevent leakage of air through the base and the fuel bed when the fire is to be banked or checked.

GENERAL SUGGESTIONS ON THE FIRING OF DIFFERENT FUELS.

Fundamentally, the process of combustion is the same for all fuels. Whether the fuel be wood, coal, or oil, heat is produced by the carbon or other combustible elements combining with the oxygen of the air. The oxygen and these combustible elements unite in certain proportions at certain temperatures and a definite quantity of heat is evolved in each case. Some of the heat is absorbed by other parts of the fuel, heating them to ignition temperature, and some of the heat is absorbed by the nitrogen in the air supplied—ordinary air contains about 80 per cent nitrogen—and by the gaseous products of combustion, raising them to a high temperature. Part of the heat radiated from the glowing fuel or conveyed by the hot gases passes over the heating surfaces of the boiler or furnace, is taken up by the water or air heated, and is distributed to the rooms of the house.

The admission of more air through the fuel bed or fire door than is required to furnish the oxygen necessary for complete combustion tends to cool the fuel bed and the gases that rise from it. As oxygen unites with combustible elements in definite proportions, the theoretical amount of oxygen and hence of air needed for the complete combustion of a given weight of coal can be computed. However, in burning any kind of fuel on a grate, considerable heat is lost in unburned material if only the quantity of air theoretically required be admitted, because it is practically impossible to get all of the particles of combustible matter in the fuel to unite with all the particles of oxygen in the air theoretically required. An excess of air must always be supplied, but this excess should be neither more nor less than is necessary to insure complete combustion.

The importance of providing an inlet for the air that must enter the furnace room is frequently overlooked, especially in small, tightly-closed furnace rooms. Roughly, 150 to 300 cubic feet of air are required for each pound of coal burned, and, to prevent trouble from insufficient draft, some means for admitting this air to the furnace room must be provided. Usually enough air leaks into the furnace room through cracks and poorly fitting windows, but the tighter the construction of the room the greater the need of an air inlet.

The suggestions following have to do especially with preventing incomplete combustion and the admission of a large excess of air into the furnace, and the minimizing of the attention necessary to maintain the proper temperature in the rooms heated.

REGULATION OF DRAFT.

Whatever fuel may be selected, convenience will be promoted by having the heater large enough to maintain for at least eight hours, without attention, proper room temperatures under any weather conditions, except the most severe. If a heater will not do this, it is too small or the draft is insufficient. Satisfactory regulation of the fire will be facilitated by a proper equipment of dampers, including (1) a hand damper in the smoke pipe, (2) a check damper, also in the smoke pipe, and (3) a damper (preferably a lift damper) in the ash pit. The ash-pit damper and ash door as well as the pit itself should be so made that the supply of air under the grates can be entirely cut off by closing the door and damper, otherwise proper control of the fire will be difficult if not impossible. This is a point often neglected. If bituminous coal is to be burned a lift damper in the firing door is advisable. Slight explosions of combustible gas sometimes occur in the furnace after fuel has been put on and unless the firing door is provided with a lift damper which can open and relieve the pressure, the door itself may be blown open.

Whether the fuel be hard or soft coal, coke, or wood, the stack damper should be kept partly closed at all times except in severe weather, unless the conditions as to size of boiler and draft are such that all the available draft is regularly needed. In most cases, with the stack damper partly closed, the proper regulation can be obtained by varying the positions of the check damper and the ash-pit damper. The fire door should not be used to check the fire except in emergencies, for the reason that the cold air admitted through the open door cools the fire pot at the same time that it checks the fire.

FIRING AND CLEANING FURNACE.

Other suggestions that apply regardless of the fuel used are: Attend to the fire regularly, do not wait until it has burned low and heat is needed throughout the house. Often the need can be anticipated and by attention at the proper time trouble can be avoided. In addition, economy of fuel is more likely to be obtained by fairly uniform rates of burning than by attempting to supply a large amount of heat in a short period and then suddenly checking the fire.

Let the size of the coal fired be as nearly uniform as possible. Using coal of uneven size prevents an even flow of air through the fuel bed and increases the tendency of the fire to burn through in spots.

Try to keep the fuel bed free from air holes, as they cause waste of fuel and may prevent the heater from maintaining the desired temperature.

Avoid excessive shaking of the grates and thus reduce the amount of coal lost by falling into the ash pit. Ordinarily, the shaking of the

grates should be stopped as soon as bright particles begin to drop through or, under some conditions, as soon as light from the fuel bed begins to show in the ash pit.

When the demand for heat is urgent or the fire must be built up quickly, keep the fuel bed uniformly thick, but not too thick, using the coarser part of the coal and all the draft available. Air will then flow freely through the entire fuel bed and burn the coal at a maximum rate. Under such conditions the firings should be made at frequent intervals and small charges used, so that the fresh fuel will only for a short time chill the temperature of the fire pot. When heavy firings are made the fresh fuel not only increases the resistance to flow of air through the fuel bed, so that the rate of combustion is lowered, but it acts as a cold blanket to screen the heating surfaces from the radiant heat of the fuel bed.

In mild weather it is well to leave on the grates a layer of ashes under the active fuel bed. This layer will increase the resistance to the flow of air through the fuel bed and facilitate the maintenance of the low rate of combustion required in such weather; also, it will cut off some of the grate surface.

Clinkers should be kept worked out of the fuel bed, for they obstruct the flow of air through it, clog the grates, and may break the parts of shaking grates.

Keep heating surfaces, or flues as they are sometimes called if the heater be a boiler, swept clean so that they will readily absorb heat. Soot cuts down the heat-absorbing power of any heating surface very rapidly, and therefore should not be allowed to accumulate. Do not allow ashes to pile up under the grates in the ash pit, for they will seal off the air from part of the grate surface and may cause the grate bars to be burned and warped.

ASH IN DIFFERENT COALS.

Purchase coal as free from slate and ash as possible. The inert, or noncombustible, matter not only has to be removed from the ash pit or the fire pot of the heater, but prevents to a certain degree the getting of proper results from the combustible matter burned. In a delivery of coal containing much noncombustible matter the purchaser will usually be able to detect either pieces of slate or lumps of bony coal, which contain alternate bands of slate and coal. If the delivery contains an excessive amount of incombustible matter in small particles mixed with the fine coal, the evidence will be the large amount of refuse taken from the heater and the difficulty of maintaining desired temperatures in cold weather. Coals mined in different fields differ widely in the proportion of ash they contain and in the care with which they are prepared for market. Hence it is impossible to say, without a knowledge of the coal, what the

proportion of refuse should be. For some typical coals, however, figures are given below to show the proportion of ash and the average and the maximum proportion of refuse to be expected.

Noncombustible matter in anthracite and bituminous coal.

Coal.	Average proportion of ash in dry coal.	Refuse.	
		Average.	Should not exceed—
Pennsylvania anthracite:	*Per cent.*	*Per cent.*	*Per cent.*
Egg	10	13	15
Stove	12	15	17
Chestnut	14	16	18
Pea	16	18	20
No. 1 and No. 2 buckwheat	18	21	23
Yard pea	15	17	19
Bituminous:			
Eastern	8 to 14	10 to 17	12 to 19
Indiana and Illinois	8 to 16	10 to 19	12 to 21
Southern Kansas	10 to 13	12 to 16	14 to 18

CONCLUSION.

Ascertain by experiment what operating conditions produce the best results in your particular heater and adhere to them. It is impossible to give exact and detailed instructions for firing all heaters. Certain general principles have been pointed out, but the best method of applying these principles in a particular case can be determined only by experiment.

Insufficient draft is often responsible for failures of heating systems to meet requirements. The chimney or smoke pipe may be too small, or may be obstructed, or there may be leaky joints in the pipe.

FIRING ANTHRACITE.

To get the best results in firing anthracite the following recommendations are made:

Keep the fuel bed thick so that it will not burn through in spots and admit a large excess of air.

If there is a bright bed of coals over the entire grate, as there should be before a heavy charge is fired, some of the burning coal should be pushed to one side or end of the grate—the part nearest the opening where the gases leave the fire pot—and the bed of live coal made thicker there. Then fire the fresh charge so as to make the bed of approximately uniform thickness and yet leave visible a bright spot of live coal to ignite the combustible gases coming off the freshly-fired fuel. In this way combustible gases from the coal will be burned gradually and will not accumulate in the fire pot and burn with an explosion.

If the fire is low, take care not to put it out by throwing on too much fresh coal. Fire lightly, and allow each firing to become ignited before fresh coal is thrown on.

RELATIVE ADVANTAGES OF THE DIFFERENT SIZES.

Use small sizes of coal if they are available and the draft is strong enough. There may now be less advantage than formerly in burning chestnut size coal instead of stove or egg size because the demand for chestnut has raised the price to practically that of stove or furnace coal. However, in many furnaces a less amount of the small sizes appears to give the same heating effect.

Fuel bills may be reduced by burning pea size, or, better, No. 1 buckwheat, if conditions permit. If the draft is not strong enough, or if the heater is so small that the coal must be burned rapidly, the small sizes may give clinker trouble or may not give heat enough. Under such conditions it may be necessary to burn the larger sizes of coal exclusively, or at least during the most severe weather.

Householders living where the small sizes of anthracite are used for steaming purposes and are generally available can profit most by burning them. In other localities, however, there will usually be a small supply of the fine coal resulting from the breakage of the larger sizes in handling. Some dealers screen out the dust and sell the best of this fine coal under the designation "yard pea." The price at which it can be obtained will depend, of course, on the demand, but "yard pea" will always cost the householder less than stove, egg, or furnace size. A householder who buys anthracite that has been handled many times may find that the stove or egg size he ordered contains fine coal enough to increase the resistance of the fuel bed so much that the coal can not be burned fast enough to heat the house in severe weather. In such a case, it may be advisable to screen the coal with a rake or coal fork and reserve the fine coal for use in mild weather or for banking the fire.

FIRING BITUMINOUS COAL.

The wide differences among bituminous coals make it impossible to give more than general suggestions for firing them. However, certain points of difference between the methods of firing these coals and anthracite may be pointed out.

Do not spread fresh fuel over the entire surface of the fire. Bituminous coal requires more air immediately after firing than does anthracite coal or coke, and covering the entire fire not only decreases the flow of air through the fuel bed, but also lowers the temperature in the fire pot enough to cause incomplete combustion of the volatile matter distilled from the coal, and, consequently, a loss of heat up the chimney.

Use some coking method of firing; that is, work the partly burned coal, from which the gas has been driven, to one part of the fire and throw the fresh coal on the remaining portion. The fresh fuel then

ignites slowly, the combustible gas is driven off gradually, and the live coals that are exposed on one part of the fire heat this gas and the air coming through the fuel bed so that more of the gas is burned before it leaves the fire pot. If, on the other hand, fresh coal is spread uniformly over the entire surface of the fire, much of the gas driven off is not ignited and escapes unburned. Figure 1 shows how this coking method may be used in firing a heater having a round fire pot, and figure 2 how it may be used for a rectangular fire pot.

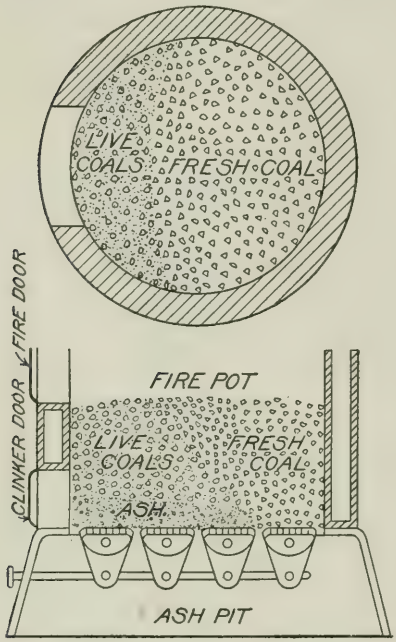

FIGURE 1.—Round fire pot fired by coking method.

Keep the flue surfaces clean and the cleaning doors tightly closed. The cleaning of the flues should be given regular and frequent attention or it is apt to be overlooked entirely.

BANKING THE FIRE.

When preparing the fire to last overnight or for a similar length of time, push some of the burning coal aside and fire the fresh charge so as to leave a bright spot visible to ignite the distilled gases. The drafts should then be allowed to stand open for a short period, possibly half an hour, before they are closed for the night, so that part of the volatile matter or gases in the coal can be driven off before the air supply is greatly reduced. In adjusting the air supply for the night use the ash-pit damper or slide and the check damper in the smoke pipe. If the ash pit is tight the firing door can and should be kept closed, or part of the heat of the fuel will be wasted in heating the cold air entering above the fire. The quantity of fuel that will be required, and the proper adjustment of the draft will vary, of course, with weather conditions, and will have to be learned by experience.

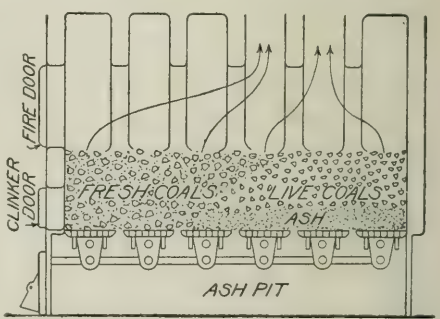

FIGURE 2.—Square fire pot fired by coking method.

FIRING COKE.

Coke can not be burned in the same way as anthracite or as bituminous coal, but with proper handling can generally be used with satisfaction where anthracite can be. In order to have a coke fire last as long and develop as much heat, approximately as many pounds of coke must be fired as of anthracite. The volume of coke, however, will be much greater than that of anthracite, and usually the fire pot will have to be filled completely to hold the fire a considerable period. Coke makes a very porous fuel bed; hence the control of drafts is important. Ordinarily some ashes can be left on the grate and they will make draft control easier.

The proper regulation of draft must be learned by experience in any case, but some general instructions may be given. Before firing a fresh charge be sure that there is a fair bed of fuel remaining from the last firing and that it is thoroughly aglow. If necessary fire a small quantity and let it become well ignited before putting in the main charge. Let drafts stay on for a short time after the new charge is fired, then they may be checked. Coke of uniform size is desirable, and for small fire pots the coke should be about nut size, whereas for larger fire pots coke of stove or egg size may be satisfactorily used.

FIRING WOOD.

Unfortunately most of the equipment for burning wood is poorly developed. The principal difficulty in successfully heating a house with wood is controlling the supply of air to the fire. A wood fire may be kept for a number of hours without attention if the air can be cut off, but the fire will last only a few hours at most unless the air supply is cut off effectively. The fuel bed of a wood fire offers much less resistance to the flow of air than that of a coal fire, so that a very slight difference in air pressure, or "draft," between the furnace room and the fire pot will force through the fuel bed enough air to keep up a good rate of combustion. Even with all draft doors and slides closed, it is difficult to keep a wood fire "banked" unless the coals are covered with ashes.

TESTS AND GENERAL DEDUCTIONS.

It would be highly desirable to present results of tests that would show a householder how much fuel his own heating equipment, if properly handled, would burn or, if he were considering the installation of such equipment, just what fuel consumption might be expected with any given equipment and fuel. Such information would be appreciated not only by the householder but by architects, heating contractors, and manufacturers of heating equipment.

However, so many variables affect the consumption of fuel in heating equipment that it is impossible to tell closely what quantity of fuel will be needed. A comparison of the amount of fuel burned in heating an equal number of rooms in two houses may be as misleading as a comparison of the ice used by two families, one of which

uses much ice for the table and has a refrigerator exposed to excessive heat in a kitchen or on a porch, whereas the other uses little ice on the table and keeps its refrigerator in the cellar.

In fact it would be difficult to construct and equip two houses in such a way that the same quantity of fuel would be required to maintain the same temperature conditions in both, and it would be difficult to buy fuel of such quality that the same quantity would be required for each house if all other conditions were exactly comparable.

Within the last few years some of the leading manufacturers of house-heating boilers have adopted the policy of testing every type of boiler they manufacture and are now publishing, or furnishing on application, the characteristic "economic-performance curves" for each of their boilers when burning different kinds of coal at all probable rates of combustion.

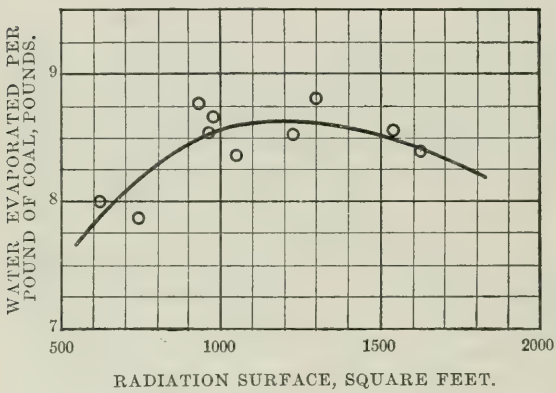

FIGURE 3.—Economic-performance curve for eight-section cast-iron boiler.

From these performance curves the architect and engineer can plan to better advantage heating equipment for small residences, apartment houses, and office buildings. One of these "economic-performance curves" is shown in figure 3.

Of the published tests of house-heating equipment the greater number were conducted for the purpose of comparing the merits of different fuels for use in such equipment. Tests of this character were made at the Government fuel-testing plant at St. Louis,[a] at the engineering experiment station of the University of Illinois,[b] and at the engineering experiment station of the Iowa State College of Agriculture and Mechanical Arts,[c] but in none of these tests were residence heating conditions actually maintained. Therefore the results, although valuable as indicating the behavior of the coals and their probable evaporative power in certain types of boilers at low but fairly uniform rates of combustion, are not of great assistance in determining how much fuel would be needed to heat a certain house.

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[a] Randall, D. T., Tests of coal and briquets as fuel for house-heating boilers: Bull. 27, Bureau of Mines, 44 pp., reprint of U. S. Geol. Survey Bull. 383.

[b] Snodgrass, J. M., Fuel tests with house-heating boilers: University of Illinois Eng. Exp. Station Bull. 31, 1909, 108 pp.

[c] Meeker, W. H., and Wagner, H. W., House-heating fuel tests: Eng. Exp. Station, Iowa State College, Bull. 33, 1913, 85 pp.

DATA ON FUEL CONSUMPTION AT RESIDENCE IN NEW HAVEN, CONN.

The authors are indebted to Prof. E. H. Lockwood, of the Sheffield Scientific School, Yale University, for the following carefully kept record of the fuel consumed in heating his own residence during the heating season of 1912–13. The record is presented just as received, except for the omission of certain names. It is regrettable that other and equally complete records of fuel consumption for heating small residences are not available:

Memorandum of fuel consumed in heating a small residence.

[Reported by E. H. Lockwood.]

LOCATION AND EXPOSURE.

1. Location of house.....New Haven, Conn.
2. Street.....52 Division Street.
3. Exposure.....North and east, sheltered by trees; west, protected by a house 20 feet distant.

DESCRIPTION OF HOUSE.

4. Construction.....Frame, clapboard on first floor, shingle on second floor, slate roof.
5. Number of stories.....2, plus attic and cellar.
6. Number of rooms heated by heating system.....10.
7. Windows.....Good condition, single glass windows, with storm windows on north side.

DIMENSION OF ROOMS AND RADIATION INSTALLED.

	Floor.	Room.	Floor Space in Feet.	Volume in Cubic Feet.	Amount of Hot-Water Radiation Installed, in Feet.
8.	First	Parlor	13 by 14	1,300	52
9.	Do	Dining	14 by 16	2,030	61
10.	Do	Living	16 by 20	2,800	150
11.	First and second	Hall	8 by 10	1,200	65
12.	Second	Bedroom	12 by 14	1,320	31
13.	Do	do	13 by 14	1,450	35
14.	Do	do	11 by 11	980	22
15.	Do	do	9 by 11	700	26
16.	Do	Bathroom	6 by 8	400	13
17.	Attic	Bedroom	10 by 12	850	26

FURNACE AND HEATING SYSTEM.

18. Heating system.....Hot water, direct radiation.
19. Kind of heater.....———, hot water, size ———, No. 2.
20. Diameter of fire pot.....20 inches.
21. Area of grate surface.....2.2 square feet.

22. Kind of radiators.....Cast iron, ——— make, some 19 inches high, some 33 inches high.
Total amount of hot-water radiation.....481 feet, actual.
23. *a*. Exposed double-glass surface.....130 square feet.
b. Exposed single-glass surface.....286 square feet.
c. Exposed wall (plaster and clapboard).....1,750 square feet.
d. Total volume of space heated.....13,000 cubic feet.
24. Supplementary heating system.....2 fireplaces, 1 in dining room, 1 in living room.
25. Wood burned in fireplaces.....1 cord a year.
26. Kind of wood.....Oak and maple, 2-foot lengths.
27. Use of fireplaces.....Dining-room fireplace used nearly every morning in cold weather for about 1 hour; other fireplace used less, more for cheerfulness than for heating.

FUEL AND METHOD OF FIRING.

28. Kind of fuel used.....Yard pea (intermediate in size between washed pea and No. 1 buckwheat).
29. Cost of coal, delivered in bins.....$4.25 per short ton (2,000 pounds).
30. Name of dealer.....——— Coal Co., New Haven, Conn.
31. In charge of furnace.....Owner, aided by family.
32. Firing schedule in cold weather.....Coal fired at 7.30 a. m., 8.30 a.m., 1 p. m., 6.30 p. m., and 10 p. m.
33. Automatic appliances.....Clock to open pipe damper at 5.30 a. m. Used every night.

TIME FURNACE WAS OPERATED—1912-13.

34. Furnace fire started in fall.....October 2, 1912.
35. Furnace fire ended in spring (not going continuously after May 1).....May 22, 1913.
36. Number of days furnace was in operation.....219.
37. Number of weeks furnace was in operation.....31.3.
38. Number of months furnace was in operation.....7.3.

AMOUNT OF COAL BURNED, AND COST.

39. Total weight of coal burned during season.....18,780 pounds.
40. Total weight of coal burned during season.....9.4 net tons.
41. Average weight of coal burned per day.....86 pounds.
41. Greatest weight of coal burned per day (for 2 days only, January 13 and February 6).....160 pounds.
43. Smallest weight of coal burned per day.....20 pounds.
44. Maximum coal burned per week (February 7–13)..960 pounds.
45. Minimum coal burned per week (April 23–30)...160 pounds.
46. Average weight of coal burned per square foot of grate per hour on coldest day.....3 pounds.
47. Cost of coal for furnace for season.....$40.

48. Cost of wood for fireplaces for season.....$8.
49. Total yearly cost of heating house, including furnace and fireplaces. $48.

TEMPERATURES AND CALCULATED RESULTS.

50. Average daily temperature inside for whole season, assumed.....69° F.
51. Average daily temperature inside during coldest week, assumed.....66° F.
52. Average daily temperature outside for 219 days, October 2, 1912, to May 22, 1913, from records of New Haven Weather Bureau.....41.5° F.
53. Same for coldest week of winter, February 7–13, 1913.....20.7° F.
54. Constants used for obtaining heat loss from house:
    a. Double glass, per square foot per hour...0.46 B. t. u.
    b. Single glass, per square foot per hour....1.03 B. t. u.
    c. Walls (plaster and clapboard).....0.44 B. t. u.
55. Calorific value of coal was not determined, but from analysis of washed pea sold in New Haven, it was estimated at.....12,500 B. t. u.
56. Heat loss from house, figured from items 23, 50, 51, 52, 53, 54, average from October 2, 1912, to May 22, 1913, per hour.....31,000 B. t. u.
57. Same, average during coldest week from February 7–13, 1913, per hour.....50,800 B. t. u.
58. Heat theoretically available in fuel, figured from items 41, 44, 55 (assuming 1 cord of wood equal to ½ ton of coal):
    a. Average from October 2, to May 22, per hour.....47,500 B. t. u.
    b. Average during coldest week, February 7–13, 1913, per hour.....75,800 B. t. u.
59. Average furnace efficiency, figured from items 56, 57, 58*a*, 58*b*:
    a. For 219 days, October 2, 1912, to May 22, 1913.....65 per cent.
    b. For coldest week, February 7–13, 1913...67 per cent.

MISCELLANEOUS REMARKS.

Number of years same furnace has been used with this fuel by present owner.....Five years.

Experience of owner.....All rooms can be kept comfortable (70° F.) in coldest weather, except 2 rooms (items 8 and 12). These rooms have insufficient radiation and can not be heated above about 65° F. in coldest weather.

63. Use of rooms.....All rooms in the house have been used continuously and heated during entire winter.

64. Capacity of heater.....Has been ample to supply hot water at all times.

65. Method of weighing coal.....A 25-pound spring balance was hung from bracket on side of coal bin. Coal was shoveled into ordinary scuttle holding 20 pounds net, and after weighing was dumped into supply box holding 40 pounds.

The report shows not only a low cost of heating but also an economical use of fuel and illustrates what savings may be effected when the problem is given proper consideration. Yard pea could be used because the heater was large enough to burn the coal, even in the coldest weather, at a low rate of combustion per square foot of grate area. Systematic and regular handling of the fire doubtless had considerable to do with the results obtained. The cost of heating is probably $50 to $100 less than what is expended by a large number of householders who live in the same locality and have about the same heating requirements but use more expensive fuel and give their heating equipment less attention.

SUMMARY.

The most important points mentioned in this paper are as follows:

1. The amount of fuel consumed in heating a house depends on many factors. Some of the factors are within the control of the householder; others are not.

2. Both convenience of operation and consumption of fuel depend on the system of heating (and ventilation) installed, and convenience, fuel consumption, and first cost should be considered in making a selection.

3. The heater should be large enough to meet continuously and without attention for periods of eight hours the demands for heat in all weather except the most severe.

4. Heating equipment that burns satisfactorily and economically one kind or size of fuel may not be well adapted to burning another.

5. Ascertain by experiment what fuel and what method of using it are best suited to your needs. As a rule, the effort to obtain this information will be amply rewarded by the saving that will result.

6. Attend to the fire regularly and try to anticipate the demands for heat.

7. Keep the heat-absorbing surfaces of the heater free from soot and dust by regular cleaning.

8. Heating systems often fail to meet the demand for heat in severe weather because of insufficient draft. To supply additional heat, the heater must be able to burn more coal.

9. The more probable causes of insufficient draft are:

a. Chimney not high enough, or having its top too near some tall object.

b. Chimney, smoke pipe, or gas passages of heater clogged with soot or débris, sometimes through the breaking of a partition between two flues in a chimney.

c. Leaky connection of smoke pipe to heater or to chimney.

d. Accidental closing of hand damper in smoke pipe.

e. Clogging of fuel bed by clinkers.

f. Too great a length of horizontal smoke pipe between the heater and the chimney.

PUBLICATIONS ON FUEL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and applicants should limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 1. The volatile matter of coal, by H. C. Porter and F. K. Ovitz. 1910. 56 pp., 1 pl., 9 figs.

BULLETIN 2. North Dakota lignite as a fuel for power-plant boilers, by D. T. Randall and Henry Kreisinger. 1910. 42 pp., 1 pl., 7 figs.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 4. Features of producer-gas power-plant development in Europe, by R. H. Fernald. 1910. 27 pp., 4 pls., 7 figs.

BULLETIN 5. Washing and coking tests of coal at Denver, Colo., July 1, 1908, to June 30, 1909, by A. W. Belden, G. R. Delamater, J. W. Groves, and K. M. Way. 1910. 62 pp., 1 fig.

BULLETIN 6. Coals available for the manufacture of illuminating gas, by A. H. White and Perry Barker, compiled and revised by H. M. Wilson. 1911. 77 pp., 4 pls., 12 figs.

BULLETIN 7. Essential factors in the formation of producer gas, by J. K. Clement, L. H. Adams, and C. N. Haskins. 1911. 58 pp., 1 pl., 16 figs.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

BULLETIN 13. Résumé of producer-gas investigations, October 1, 1904, to June 30, 1910, by R. H. Fernald and C. D. Smith. 1911. 393 pp., 12 pls., 250 figs.

BULLETIN 14. Briquetting tests of lignite at Pittsburgh, Pa., 1908–9; with a chapter on sulphite-pitch binder, by C. L. Wright. 1911. 64 pp., 11 pls., 4 figs.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 18. The transmission of heat into steam boilers, by Henry Kreisinger and W. T. Ray. 1912. 180 pp., 78 figs.

BULLETIN 23. Steaming tests of coals and related investigations, September 1, 1904, to December 31, 1908, by L. P. Breckenridge, Henry Kreisinger, and W. T. Ray. 1912. 380 pp., 2 pls., 94 figs.

BULLETIN 24. Binders for coal briquets, by J. E. Mills. 56 pp., 1 fig. Reprint of United States Geological Survey Bulletin 343.

BULLETIN 27. Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. 44 pp., 3 pls., 2 figs. Reprint of United States Geological Survey Bulletin 366.

BULLETIN 28. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 51 pp. Reprint of United States Geological Survey Bulletin 323.

BULLETIN 29. The effect of oxygen in coal, by David White. 80 pp., 3 pls. Reprint of United States Geological Survey Bulletin 382.

BULLETIN 31. Incidental problems in gas-producer tests, by R. H. Fernald, C. D. Smith, J. K. Clement, amd H. A. Grine. 29 pp., 8 figs. Reprint of United States Geological Survey Bulletin 393.

BULLETIN 32. Commercial deductions from comparisons of gasoline and alcohol tests of internal-combustion engines, by R. M. Strong. 38 pp. Reprint of United States Geological Survey Bulletin 392.

BULLETIN 33. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by W. T. Ray and Henry Kreisinger. 50 pp., 10 figs. Reprint of United States Geological Survey Bulletin 403.

BULLETIN 34. Tests of run-of-mine and briquetted coal in a locomotive boiler, by W. T. Ray and Henry Kreisinger. 33 pp., 9 figs. Reprint of United States Geological Survey Bulletin 412.

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BULLETIN 88. The condensation of gasoline from natural gas, by G. A. Burrell and F. M. Seibert. 1915. 102 pp., 18 figs., 6 pls.

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